THE CRETACEOUS STRATIGRAPHY OF SOUTH-CENTRAL AFRICA

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(With 10 figures)

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INTRODUCTION

Recent studies by Reyment (1969, 1971) have led him to suggest that 'Cretaceous (Albian to Turonian) transgressions around the coast of Africa display a correlative pattern that suggests they may be the results of a see-saw motion' (1971: 1063). Field-work and biostratigraphical studies in Angola, the south-east Cape, Zululand and southern Moçambique do not support this conclusion. A study of the Cretaceous deposits of southern and central Africa suggests the observed sequence of transgressions and regressions can best be explained by eustatic sea-level changes, together with local coastal warping, rather than oscillatory tiltings of the African continent.

STRATIGRAPHY OF THE WEST COAST

Along the west coast of Africa south of the Sahara, i.e. south of latitude 20°N, deposits of Cretaceous age are known from many localities. The occurrence of these sequences is important in the study of the break-up of Gondwanaland and the early history of the South Atlantic Ocean.

According to Furon (1963: 232), the first genuine marine horizon in Ghana is 'that of the Anwiafutu Limestone with *Plicatula auressensis* and *Exogyra olisiponensis*', considered to be of Upper Cenomanian–Turonian age, whilst the earliest marine beds in the Ivory Coast and Upper Volta are assigned to the Upper Cenomanian on the basis of *Plicatula fourneli* Coquand.

The Cretaceous biostratigraphy of Nigeria (Fig. 1) is well known following the studies of Reyment (1954*a*, 1954*b*, 1955, 1965) and Barber (1957). The earliest recorded marine beds contain *Oxytropidoceras* of low Middle Albian age, this genus dating the maximum transgression of the Albian in Nigeria (Reyment 1955). The remainder of the Albian appears to be present and is in places highly fossiliferous. Undoubted Cenomanian is known only from Calabar Province (Reyment & Tait 1972), where deposits with *Euhystricoceras*, *Turrilites*, *Forbesiceras*, *Acompsoceras* and *Acanthoceras quadratum* Crick occur on the coast. *Euhystricoceras* is confined to Lower Cenomanian strata while the remaining forms are typical of the Middle Cenomanian. The only Upper Cenomanian

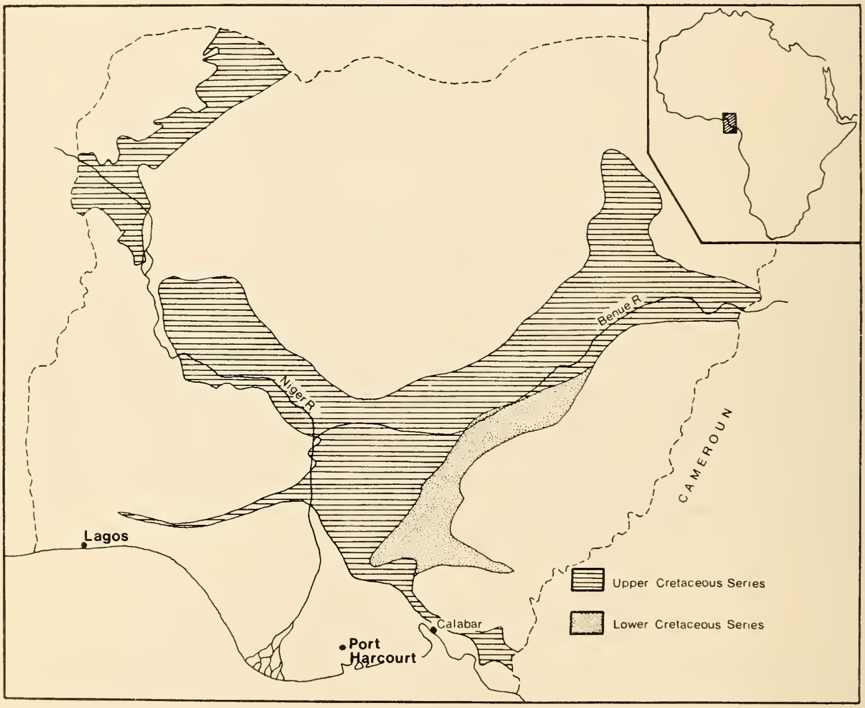

Fig. 1. The Cretaceous outcrop in Nigeria. After Reyment 1955.

species so far recorded (Reyment & Tait 1972) is *Metoicoceras* aff. *ornatum* Moreman (= *M. whitei* Hyatt), which indicates an uppermost Cenomanian age (Kennedy 1971).

The Lower Turonian of Nigeria is very rich in ammonites (Reyment 1954*a*, 1954*b*, 1955; Barber 1957), although Upper Turonian strata appear to be lacking in diagnostic fossils. The Coniacian is well established by the presence of the ammonites *Solgerites*, *Forresteria*, *Peroniceras* (*Peroniceras*), *P.* (*Reginaites*), *Tissotia*, and *Gauthiericeras*. Santonian (?Lower) is known from Nigeria

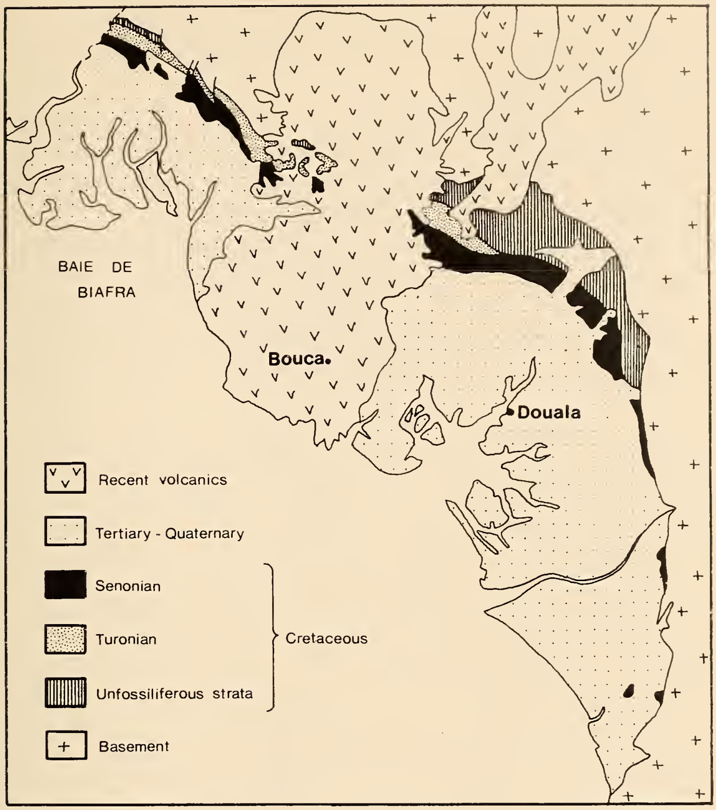

Fig. 2. The distribution of Cretaceous strata in Cameroun. After Belmonte 1966.

and Zaïre by *Texanites*. According to Reyment (1966: 171) 'The Santonian was, in the Nigerian basin, a time of regression'. This possibly explains the absence of the rich *Pseudoschloenbachia*-fauna which characterizes the Upper Santonian (Collignon 1968) of the east coast. The Campanian and Maastrichtian of Nigeria have yielded *Libycoceras*, *Sphenodiscus*, *Didymoceras* and *Baculites*.

Belmonte (1966) has summarized the latest stratigraphical data concerning the Cretaceous deposits of Cameroun (Fig. 2). Albian is known only from near the Nigerian frontier where cross-bedded sandstones and intercalated shales have yielded plant fragments. Marine Cenomanian has not yet been recorded.

In the Mungo Valley the Cretaceous 'forment une alternance d'épisodes marins transgressifs' (Belmonte 1966: 11), and Diebold (1962) has recognized three sedimentary cycles.

The first cycle is a transgressive sequence dated at upper Lower Turonian by the ammonites *Kamerunoceras*, *Neoptychites*, *Choffaticeras*, *Hoplitoides*, etc. The second cycle is a regressive phase dated at Upper Turonian by *Romaniceras* aff. *uchauxiense* (Collignon) and *R.* aff. *deverioides* (de Grossouvre). A transgressive sequence with *Tissotia*, *Barroisiceras*, and *Peroniceras*, dated at Coniacian, constitutes the third cycle.

The Santonian is well developed in the Douala basin, where a marine intercalation has yielded *Texanites quattuornodosus* (Lasswitz) and *T.* aff. *soutoni* (Baily). Reyment (*in* Müller 1966: 140) has recorded the Upper Santonian *Pseudoschloenbachia* from the Mungo River Formation.

In the Douala basin the Campanian is represented by a transgressive sequence yielding the ammonites *Eupachydiscus*, *Karapadites*, *Menabites*, and *Parapuzosia*. These forms suggest a Middle to Upper Campanian age. The presence of *Parapachydiscus stallauense* Imkeller is taken to provide evidence of the Maastrichtian, since this species is known from the Lower Maastrichtian of Nigeria.

The earliest marine horizon in Gabon has yielded an ammonite, the Lower Aptian *Deshayesites consorbinoides* Sinzow according to De Klasz & Gageonnet (1965: 285), although Reyment & Tait (1972) consider it better referred to the Upper Aptian genus *Neodeshayesites*. These beds are succeeded higher up by strata with *Douvilleiceras*, of upper Lower Albian age. Overlying beds have yielded the ammonites *Oxytropidoceras*, *Mortoniceras*, and *Elobiceras*, and probably span much of the remainder of the Albian. The Cap Lopez Formation has been assigned a Cenomanian age on the basis of foraminifers. Turonian strata with *Wrightoceras*, *Bauchioceras*, etc., is well known, although the presence of the Upper Turonian is still in doubt (Reyment & Tait 1972). Coniacian strata with *Peroniceras*, *Gauthiericeras*, and *Barroisiceras* discordantly overlie Turonian rocks (Reyment & Tait 1972). *Texanites* provides evidence of the Santonian, while Upper Campanian is known from the vicinity of Libreville by strata with *Hoplitoplacenticeras* (Reyment 1966: 170).

Records of Aptian from the west coast are based largely on microfossil evidence, although the bivalve *Panis cabrai* (Dartevelle & Freneix) has been used to suggest an Aptian age for strata in Zaïre and Angola. Presumably on the basis of microfossils, Hoppener (1958: 75) recognized a 'transgression aptienne inférieure ou ante aptienne', and a 'transgression aptienne supérieur' from Angola. No ammonites have yet been collected to support this contention.

In Angola (Fig. 3) the earliest undoubted marine beds occur at Dombe Grande, to the south-east of Benguela, and have yielded the ammonites *Douvilleiceras mammillatum inaequinodum* (Quenstedt) and *D. orbignyi* Hyatt (Howarth 1965). The beds immediately above are rich in *Oxytropidoceras* and *Manuaniceras*. These upper Lower Albian–lower Middle Albian beds are characterized by a fauna rich in numbers but poor in species. Unfossiliferous sediments overlying these beds would seem to span the remainder of the Middle Albian and are succeeded by Upper Albian strata with *Mortoniceras*. No ammonites have been recorded from the Middle Albian strata of Angola above beds with *Oxytropidoceras*. Strata presumably of a similar age, at Hanha, the supposed fossil locality of Haas (1942*a*), are also unfossiliferous. Near Hanha,

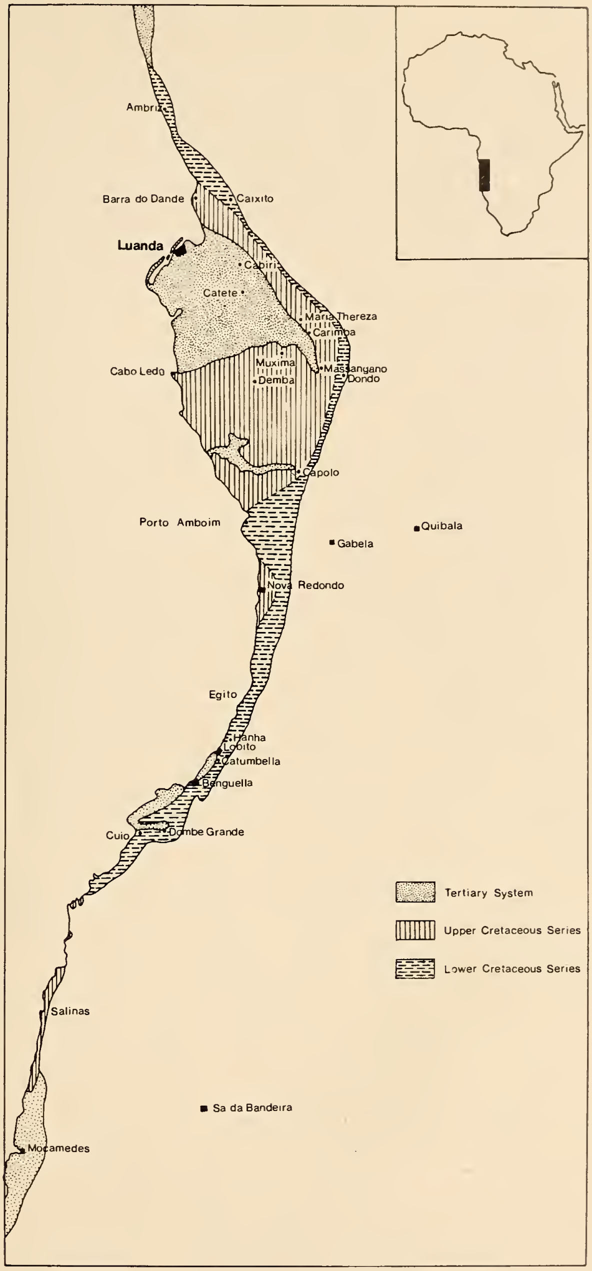

Fig. 3. Locality map showing the distribution of Cretaceous strata in Angola. In part after Mouta & O'Donnell 1933.

however, low Upper Albian strata are rich in *Neokentroceras*, *Dipoloceras*, *Mortoniceras*, etc. The remainder of the Upper Albian in Angola is frequently extremely rich in *Mortoniceras*, *Elobiceras*, *Prohysteroceras*, *Anisoceras* and *Stoliczkaia*. Reyment & Tait (1972), following Howarth (1965), suggested that *Stoliczkaia* was of Lower Cenomanian age in Angola, as did Kennedy (1971). This is wrong. This misconception has arisen from Douvillé's (1931) record of *Stoliczkaia dispar* var. *attenuata* Douvillé from the uppermost Cenomanian of Salinas (Cooper 1972). Further topotype material suggests that this specimen belongs not to this Upper Albian–Lower Cenomanian genus, but should rather be considered the homeomorphous development of some other acanthocerate stock, possibly the early Turonian *Benueites* (W. J. Kennedy, pers. comm.). The uppermost Albian of Angola, as exposed at Egito, is characterized by *Anisoceras perarmatum* Pictet & Campiche, *Stoliczkaia* spp., and mortoniceratids.

At Egito the lowest fossiliferous horizons, resting upon crystalline basement, have yielded *Mortoniceras*, suggesting the beginning of the Upper Albian to have been a period of transgression. As noted by Reyment (1969), uppermost Albian deposits occur closest to the coast, e.g. Egito, Catumbela, suggesting a gradual regression following the early Upper Albian transgression.

Deposits at Salinas indicate the uppermost Cenomanian to have been a period of transgression, yielding the ammonites *Calycoceras naviculare* (Mantell), *Austiniceras dibleyi* Spath, *Pseudocalycoceras angolaense* (Spath), *Sciponoceras gracile* (Shumard), *Kanabiceras septemseriatum* (Cragin) and *Metoicoceras* cf. *whitei* Hyatt. The overlying beds comprise a condensed sequence spanning Turonian and earliest Coniacian times (Cooper 1972), and contain the following ammonite genera: *Mammites*, *Subprionocyclus*, *Damesites*, '*Prionocyclus*', *Hauericeras*, *Baculites*, *Kossmaticeras*, ?*Subtissotia*, *Proplacenticeras*, *Gaudryceras*, *Hypophylloceras*, *Anagaudryceras*, and *Mesopuzosia*. The rich and varied Turonian fauna of Nigeria is not known from Angola. These beds are disconformably overlain by subaerially extruded alkaline volcanics of Upper Coniacian age (Cooper 1972), in turn succeeded by early Santonian marine beds with *Protexanites*, *Texanites*, *Hauericeras* and *Damesites*.

The stratigraphy of the Cuanza basin is at present poorly known. Hoppener (1958) assigned an Upper Aptian age to oolitic limestones near the base of the succession with *Acteonella* aff. *fusiformis*, *Cerithium* cf. *albense*, and *Perna* sp. while a rich Upper Albian fauna is known from Cabo Ledo.

At the beginning of Cenomanian times the sea transgressed in Angola, with *Sharpeiceras laticlavum* (Sharpe) occurring at Cabiri, while in the south of the Cuanza basin, at Novo Redondo, the transgression extended about 20 km inland, the lowest beds yielding the Lower Cenomanian *Mantelliceras* cf. *saxbii* (Sharpe) (Cooper 1973*b*). There was probably a gradual regression until Middle Cenomanian times, since beds with *Turrilites acutus* Passy, *Euomphaloceras cunningtoni* (Sharpe), *Forbesiceras obtectum* (Sharpe), etc., occur at the coast. No higher beds are known from Novo Redondo. Haas (1942*b*) recorded a *Romaniceras* sp. from north of Cabiri, which suggests a Turonian age. Hoppener

(1958) also assigned a Turonian age to *Coilopoceras cacobaensis* sp. nov. (a *nomen nudum* since it was neither figured nor described). Downfaulted strata at Cabo Ledo have yielded an uppermost Turonian fauna with *Prionocyclus* and *Subprionocyclus* (Basse 1963; Matsumoto 1965: 49; Howarth 1968: 225). Of probable Coniacian age is *Proplacenticeras reineckei* (Haughton), while Hoppener (1958) assigned '*Placenticeras*' *fritschi* Hyatt and a *Hemitissotia* sp. to the Coniacian. The occurrence of *Texanites angolanus* Haas and *T. quinquenodosus* (Redtenbacher) to the north of Cabiri provides evidence of the Santonian. A rich, predominantly heteromorph fauna from Barra do Dande suggests an Upper Campanian–Maastrichtian age (Howarth 1965; Antunes & Sornay 1969). Amongst the genera recorded are *Didymoceras*, *Nostoceras*, *Manambolites*, *Solenoceras*, *Axonoceras*, *Polyptychoceras*, and *Sphenodiscus*. Antunes & Sornay (1969) consider these beds, the Barra do Dande Formation, to rest (?) disconformably upon the Pambala Formation which they tentatively dated at Upper Santonian–Lower Campanian on the basis of inoceramids assigned to the *bantu–balticus* group. No ammonites have been collected to support this evidence. The apparent absence of *Hoplitoplacenticeras* at Barra do Dande, a common ammonite in the Upper Campanian fauna of the Egito outlier, suggests that the transgression may have been slightly diachronous, occurring earlier in the south than in the north. From far inland, at Carimba, Haughton (1925) recorded *Nostoceras*, *Didymoceras*, *Menuites*, *Libycoceras*, etc., for which an Upper Campanian–Lower Maastrichtian age appears the most precise dating. A similar age seems the most likely for Haas's (1943) fauna from the Maria Theresa area. A major transgression undoubtedly took place in Angola during Upper Campanian–Maastrichtian times. The base of the transgression is not known from the Cuanza basin, but at Egito is dated at Upper Campanian (*vari* Zone) probably reaching its maximum extent somewhat later. At San Nicolau, a horizon rich in sharks' teeth was assigned to the Maastrichtian (Dartevelle 1942). Cooper (1972), on sedimentalogical grounds, doubted this age determination. In retrospect, however, the occurrence of phosphatic pellets associated with the sharks' teeth suggests the possibility of a non-sequence. Should such a break exist, then these beds possibly represent the base of the late Campanian transgression.

From the Cavaco valley near Benguela, Spath (1951: 124) recorded a 'presumed Campanian' fauna with *Inoceramus langi* Choffat and ammonites tentatively identified as *Hauericeras gardeni* (Baily), *Damesites*, and *Neancyloceras* from clays resting unconformably upon Upper Albian strata.

Haughton (1930) described a small inlier of marine Cretaceous from Bogenfels in South West Africa, from which he recorded the ammonite *Proplacenticeras merenskyi* (Haughton) in association with the oyster *Exogyra* cf. *columba* (Lamarck) (= *Rhynchostreon suborbiculatum* (Lamarck)), these beds being characterized by the abundance of the latter. At Salinas in southern Angola, the uppermost Cenomanian is characterized by the abundance of *Rhynchostreon* cf. *suborbiculatum* (Cooper 1972), which is absent from the overlying beds, nor has it been recorded from the Middle Cenomanian of Novo Redondo. An uppermost Cenomanian age would appear the most likely for the Bogenfels outlier. H. C. Klinger (pers. comm.), who has personally visited the Wanderfeld IV locality of Haughton, considers the Cretaceous fauna to, in all probability, represent remanié, although in this respect the apparent abundance of the diagnostic Cenomanian oyster *R. suborbiculatum* is critical. Haughton (1930) believed these '*Exogyra* beds' to be unconformably overlain by the Senonian with *Protocardia hillana* (Sowerby), *Turritella* (*Zaria*) *bonei* Baily and *T.* (*Haustator*) *meadi* Baily. Together these forms suggest a possible Santonian age.

STRATIGRAPHY OF THE SOUTH COAST

Along the south coast of South Africa (Fig. 4), marine strata at Knysna, long correlated with the Uitenhage Group, have been assigned 'A high Mid-Kimmeridgian age' (Klinger *et al.* 1972) on the basis of the ammonite

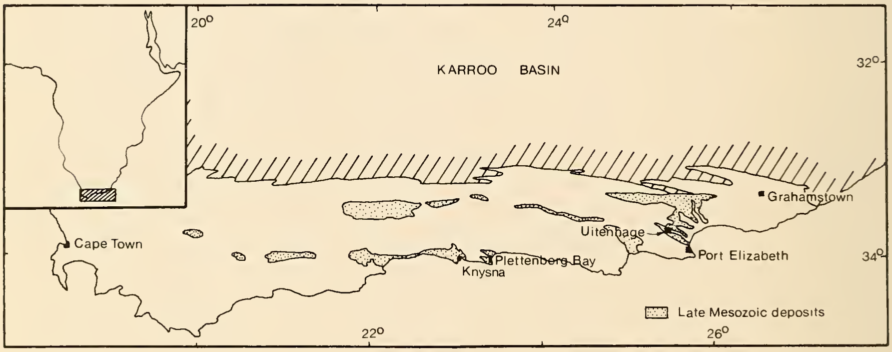

Fig. 4. The distribution of late-Mesozoic strata in the southern Cape. After Geol. Surv. S. Afr. 1970.

Hybonoticeras aff. *hildebrandti* (Beyrich), while Dingle & Klinger (1972) recorded an ostracode assemblage with strong Callovian affinities. These are the earliest Mesozoic marine sediments to be recorded from South Africa. At Robberg, near Plettenberg Bay, casts of *Megatrigonia conocardiiformis* (Krauss) occur in sandstones of the Enon Formation of the Uitenhage Group, and are probably of Upper Jurassic age, since this species is also known from the Upper Kimmeridgian–Tithonian of Moçambique (Da Silva 1966).

To the north of Port Elizabeth, sediments assigned to the Uitenhage Group (Cooper 1973*a*) crop out over wide areas, although it is only the upper portion, the Sundays River Formation, that has yielded ammonites. The cephalopod fauna is characterized by the abundance of species of *Olcostephanus* s.s., together with *Distoloceras*, *Bochianites*, *Eodesmoceras*, *Partschiceras*, ?*Leopoldia*, and *Belemnopsis*. The absence of finely-ribbed forms of *Olcoste-*

phanus, e.g. *O. filosus* (Baumberger), which characterize the Lower Hauterivian of France (Busnardo & Cotillon 1964), and of the subgenus *O.* (*Jeannoticeras*) favours an uppermost Valanginian age for the Uitenhage fauna.

STRATIGRAPHY OF THE EAST COAST

To the south of Port St. Johns, at the Umgazana River mouth (Fig. 5), Cretaceous conglomerates have yielded belemnites, the ammonite *Bochianites* (Du Toit (1954) records the Upper Cretaceous *Baculites*, but this is a misidentification), and the bivalve *Steinmanella* cf. *holubi* (Kitchin). Together these forms favour a correlation with the Uitenhage Group, and an uppermost Valanginian age.

A short distance to the north of Port St. Johns are outcrops of unfossiliferous strata assigned to the Emboyti Formation. Although no marine fossils have yet been recorded, the close lithological similarity with the Umgazana Formation led Du Toit (1954) to suggest a correlation.

The age of the Pondoland Umzamba Formation has long been a source of contention, but Spath (1953) was led to conclude that it represented a condensed sequence. The occurrence of *Pseudoschloenbachia*, *Lewesiceras*, *Texanites*, *Hauericeras*, *Barroisiceras*, *Eulophoceras*, *Forresteria*, *Pseudophyllites*, *Kossmaticeras* (*Natalites*), *Pseudoxybeloceras*, etc., suggests that the condensation may span Upper Coniacian to Lower Campanian times, with the majority of forms Santonian. Gevers & Little (1946) recorded an isolated outlier of Cretaceous, the Itongazi Formation, from between the Umkandandhlovu and Itongazi Rivers in southern Natal. Although no ammonites have yet been recorded, the majority of bivalves and gastropods are also common to the Umzamba Formation, and leave little doubt as to their contemporaneity.

Two quarries at Need's Camp, near East London, have yielded Upper Senonian faunas although no diagnostic forms have been reported. On foraminiferal evidence, McGowran & Moore (1971) have assigned the Lower Quarry an Upper Campanian–Maastrichtian age. The commonest macrofossils are well-preserved sharks' teeth, assigned to *Isurus* and *Carcharias*, the coral *Caryophyllia*, and bryozoans, together with the echinoid *Coptosoma*, the brachiopod *Lacazella*, and the bivalves *Exogyra*, *Neithea*(?) and *Inoceramus*. A similar age has been assigned to the Upper Quarry (King 1972), long considered of Eocene age, also on foraminiferal evidence. Macrofossils from this quarry include teeth of the sharks *Oxyrhina*, *Odontaspis* and *Carcharodon*, the gastropod *Pyropsis*, and the bivalves *Plicatula*, *Panopea* and *Lima*. No ammonites have been recorded from either quarry. Lock (1973), however, considers the Upper Quarry to be Miocene in age, with incorporated Cretaceous and Eocene remanié.

Kennedy *et al.* (1973) have recently described an Upper Santonian–Campanian borehole fauna from Durban, including the following species: *Anagaudryceras subsacya* (Marshall), *Texanites* (*Plesiotexanites*) *stangeri* (Baily),

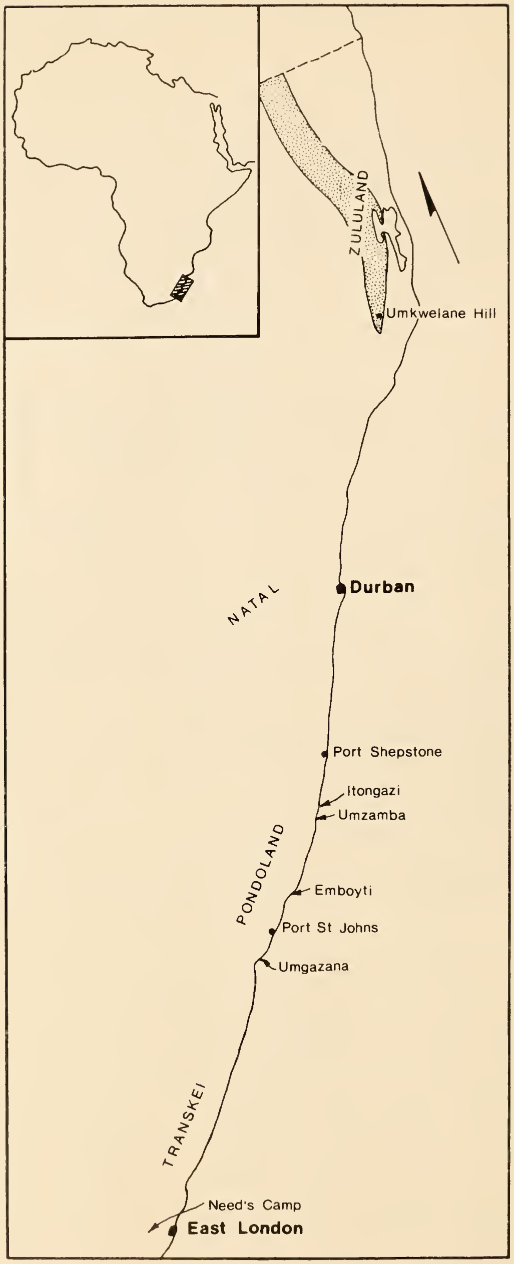

Fig. 5. Locality map showing the Cretaceous exposures along the east coast of South Africa; the Zululand outcrop is stippled. After Geol. Surv. S. Afr. 1970.

Submortoniceras woodsi (Spath), *Hoplitoplacenticeras plasticum* Paulcke, *Hauericeras* cf. *gardeni* (Baily), *Kossmaticeras* (*Natalites*) cf. *acuticostatus* (Spath), etc. These authors considered this fauna to generally resemble that of the Umzamba Formation.

In Zululand the earliest marine outcrops are of Barremian age (W. J. Kennedy and H. C. Klinger, pers. comm.), with the ammonites *Heteroceras*, *Colchidites*, *Phylloceras serum* Oppel, *Eulytoceras phestum* (Matheron), etc. The occurrence of *Tropaeum*, *Australiceras*, *Cheloniceras*, *Acanthohoplites*, and *Diadochoceras* (Haughton *in* Rennie 1936) indicates most of the Aptian to be present. Beds containing *Diadochoceras* are overstepped by strata with *Douvilleiceras mammillatum* (Schlotheim) (Kennedy & Klinger 1971); thereafter deposition appears to have been continuous until the low Upper Cenomanian with *Calycoceras* gr. *naviculare* (Mantell), although after deposition of beds with *Acanthoceras quadratum* Crick, *A.* spp., *Turrilites acutus* Passy, *Calycoceras* spp., *Forbesiceras largilliertianum* (d'Orbigny), etc., the sequence is poorly fossiliferous. These beds are unconformably overlain by Lower Coniacian strata (Kennedy & Klinger 1971) with *Proplacenticeras subkaffrarium* (Spath), *P. umkwelanense* (Etheridge), *P. kaffrarium* (Etheridge), *Kossmaticeras theobaldianum* (Stoliczka), *Bostrychoceras indicum* (Forbes), etc., followed by continuous deposition until the Lower Maastrichtian with *Eubaculites*, *Pachydiscus* (*Neodesmoceras*), and *Saghalinites*. The uppermost Cenomanian and Turonian was a period of non-deposition, the hiatus being represented by a *Lithophaga*-bored hardground.

The earliest recorded marine horizon in Moçambique, at Nacala (Fig. 6), has been dated at Upper Kimmeridgian–Tithonian (Da Silva 1966) on the basis of the bivalves *Trigonia* (*Indotrigonia*) *smeei* auct. and *Astarte krenkeli* Dietrich. A cephalopod from these beds has not yet been described.

Slightly further to the north, at Fernão Veloso, strata with *Olcostephanus schenki* (Oppel) (=*O. baini* (Sharpe)) and *Haploceras* (*Neolissoceras*) cf. *grasianum* (d'Orbigny) (Wray 1915; Spath 1930) provide evidence of the uppermost Valanginian. Strata of a similar age also crop out at Mahiba Hill, west of Port Amélia, from where Newton (1924) recorded fragments of *Lytoceras*, together with the belemnite *Duvalia*. From this same locality, Spath (1930: 134) also records a 'portion of the periphery of a Neocomitid (*Lyticoceras* of the type of *L. regalis* (Bean) or *Neocomites neocomiensis* (d'Orbigny) as figured by Sayn), and the impression of a fragment of the Uitenhage *Bochianites africanus* are decisive and unmistakable'. Neumayr (1885) recorded the Neocomian *Phylloceras semistriatum* (d'Orbigny) from the Moçambique region, an identification subsequently confirmed by Zwierzycki (1913).

Aptian and Albian strata are best known from southern Moçambique (Fig. 7), although exposures are poor and much of the area is capped by younger Neogene deposits.

The best exposures are at Catuane, the so-called Maputoland locality of Spath (1925), where the earliest beds have been assigned to the Upper Aptian

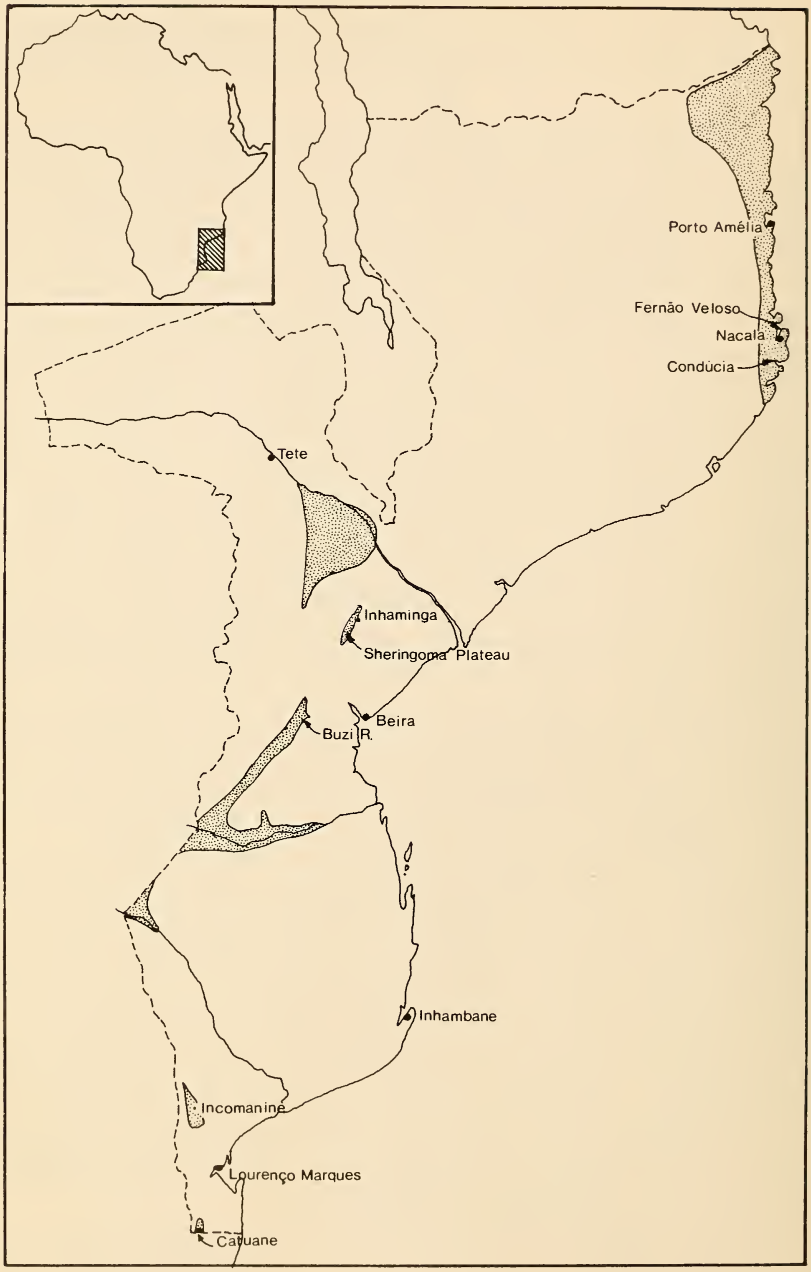

Fig. 6. The distribution of late-Mesozoic strata in Moçambique. Largely after De Freitas 1957.

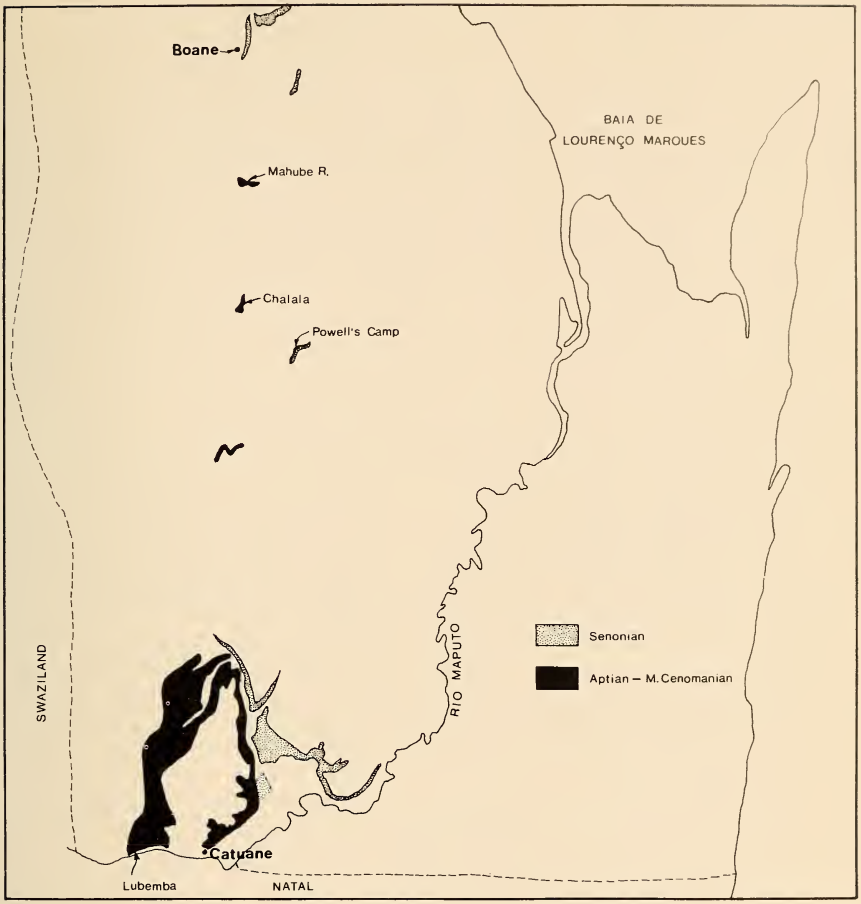

Fig. 7. The Cretaceous exposures of southern Moçambique. After Serviços de Geologia e Minas da Provinçia de Moçambique, 1969.

(Da Silva 1962; Wachendorf 1968). On the farm Lubemba, from where both Da Silva's and Wachendorf's collections came, recent collecting has yielded a rich Lower Aptian (*deshayesi–bowerbanki* Zones) fauna dominated by the abundance of *Cheloniceras* (*Cheloniceras*), together with the genera *Tropaeum*, *Ancyloceras*, '*Neosilesites*', '*Valdedorsella*', *Phylloceras*, *Toxoceratoides*, *Pseudosaynella*, etc. Wachendorf (1968) records *Parahoplites campichei* Pictet & Renevier and *P. melchioris* Anthula from the Maputo River which provide evidence of the Upper Aptian at this locality as well. The occurrence of *Phylloceras* at Lubemba, which Da Silva (1962) thought to resemble *P. velledae* (Michelin), led him to suggest the presence of Albian at this locality. This is incorrect. Recent collecting has shown the *Phylloceras* to be closely associated with *Cheloniceras* (*Cheloniceras*), and thus of Lower Aptian age. No Lower

Albian fossils have yet been recorded from Catuane. The presence of the Middle Albian is indicated by the occurrence of *Oxytropidoceras*, while Spath (1925) has recorded a rich low Upper Albian fauna characterized by the heteromorphs *Anisoceras*, *Labeceras*, and *Myloceras*, together with *Mortoniceras*, *Elobiceras* and *Hysteroceras*. The uppermost Albian (*dispar* Zone) has not been recorded, but its presence is to be suspected. Spath (1925) described *Sharpeiceras florencae* Spath from Maputoland, and thus presumably Catuane. This genus is confined to the Lower Cenomanian. The occurrence of *Trigonarca* cf. *ligeriensis* (d'Orbigny), *Pterotrigonia* (*Scabrotrigonia*) *shepstonei* (Griesbach), and *Amphidonte columba* (Lamarck) (= *Rhynchostreon suborbiculatum* (Lamarck)) from 3 km to the east of Catuane, led Soares & Da Silva (1970) to suggest the presence of the Cenomanian. This is confirmed by the recent collection of a worn fragment of *Calycoceras* from this area. These beds are unconformably overlain by the Mandajene Formation. Amongst 52 species of bivalves and gastropods recorded from this formation (Soares & Da Silva 1970), 31 are common to the Umzamba Formation of Pondoland. Soares & Da Silva (1970: 2) considered the Mandajene Formation to be 'of Santonian–Campanian age, or even Maestrichtian towards Santana de Tinonganine'. Unfortunately, these beds are poor in ammonites. Internal moulds of baculitids were compared with *Baculites capensis* Woods (Soares & Da Silva 1970), while Spath (1925) recorded *Texanites* aff. *soutoni* (Baily) from Maputoland, and presumably, therefore, from this region. The dating of the base of the Senonian transgression in Zululand, of which succession the Catuane deposits are merely a continuation, at Lower Coniacian (Kennedy & Klinger 1971) suggests a similar age for the base of the Mandajene Formation.

Cretaceous strata are again exposed to the west of Porto Henrique, at the renowned Chalala locality (Haughton & Boshoff 1956; Wachendorf 1968), where the presence of *Cheloniceras* (*Cheloniceras*), *Toxoceratoides*, *Aconeceras*, *Acrioceras*, and *Phylloceras* provide evidence of the upper Lower Aptian (*deshayesi–bowerbanki* Zones). Lacey (1961) recorded the presence of *Bostrychoceras* and *Calycoceras* at Chalala, to which he assigned a Cenomanian or Lower Turonian age. The heteromorph fragment was assigned to *Bostrychoceras* on the basis of its rounded whorls and non-tuberculate ribs, while 'The smaller fragment . . . has tubercles and appears to be an indeterminate species of *Calycoceras* which has an age span of Cenomanian to Lower Turonian. Very similar forms such as the Aptian *Cheloniceras* or *Roloboceras* would appear to be excluded by the presence of *Bostrychoceras*, since forms with round whorls and non-tuberculate ribs do not occur before the Cenomanian' (p. 9). These are almost certainly misidentifications since a recent visit to Chalala revealed only friable, unfossiliferous Neogene (?) deposits resting disconformably, with a basal small-pebble conglomerate, upon Lower Aptian strata. Further to the north-east, however, Upper Albian beds with *Mortoniceras*, *Hysteroceras* and *Labeceras* are exposed and are overlapped by Middle Cenomanian strata with *Acanthoceras*.

To the south-east of Porto Henrique, rocks of Cretaceous age are exposed on the Catembe River. Presumably this is the Powell's Camp locality of Spath (1921), from where he described *Aconeceras nisoides* (Sarasin), *Cheloniceras gottschei* (Kilian) and *C. delagoense* (Krenkel), considered to be of Upper Aptian age. There is little doubt that these beds should be correlated with the other similar deposits of southern Moçambique, and be considered of upper Lower Aptian age.

Lower Aptian strata are again exposed along the Mahube River, where the genera *Aconeceras*, *Toxoceratoides*, and *Cheloniceras* were collected. These beds are overlain by the Cenomanian (Soares & Da Silva 1970), characterized by the abundance of *Turrilites costatus* Lamarck, virtually to the exclusion of all else. Soares & Da Silva (1970) have also recorded *Acanthoceras* from this locality. It seems likely that these beds can be correlated with the '*Turrilites costatus* faunal assemblage' of Kennedy (1971), of low Middle Cenomanian age.

Kilian (1902) and Krenkel (1910) both described Aptian fossils collected from 'Delagoa Bay'. No Cretaceous is exposed around Delagoa Bay, and this locality is obviously the regional name applied by the early travellers.

The only other early Cretaceous deposit known from Moçambique is the rich Upper Albian–Cenomanian locality of Conducia, in the north, from where Choffat (1903) recorded *Anagaudryceras sacya* (=*A. choffati* Shimizu), *Mariella bergeri* (=*M. conduciensis* Breistroffer), *Phylloceras semistriatum* d'Orbigny, ?*Baculites* sp., ?*Hamites* sp., *Desmoceras latidorsatum* (Michelin), '*Desmoceras beudanti*' var. *petersoni* Choffat, *Sharpeiceras laticlavium mozambiquense* Choffat, *Calycoceras marquescostae* (Choffat), and *Mortoniceras* cf. *candollei* (Pictet).

Cox (1925) described an entirely new gastropod fauna from Incomanini, to which he assigned an Upper Maastrichtian age, a determination supported by a study of the bivalves (Rennie 1935). The Maastrichtian is also present along the Buzi River and at Sheringoma, from where Crick (1924) has recorded *Eubaculites* cf. *vagina* (Forbes) and the nautiloids *Hercoglossa mazambensis* Crick and *H. sheringomensis* Crick.

The late Mesozoic stratigraphy of Tanzania (Fig. 8) is not well known. 'Nowhere is there good dating below the Callovian, but a considerable part of the Ruvu Beds (q.v.) is apparently Bajocian/Bathonian in age' (Quennell *et al.* 1956: 156). To the east of the Ngarama Plateau sediments assigned to the Mandawa–Mahokondo 'Series' have yielded Upper Oxfordian (*plicatilis*-Zone) ammonites of the genera *Perisphinctes* (*Arisphinctes*), *P.* (*Dichotomosphinctes*), and *Euaspidoceras*. From the same locality the genera *Ptychophylloceras*, *Hecticoceras* (*Sublunuloceras*), *Sindeites*, *Indosphinctes*, *Choffatia*, *Grossouvria*, *Kinkeliniceras*, etc., provide evidence of the Middle and Upper Callovian. The overlying 'Septarian Marls' have been dated at Lower Kimmeridgian (*mutabilis–pseudomutabilis* Zones) by the presence of *Streblites*, *Physodoceras*, *Idoceras*, *Taramelliceras*, *Virgatites*, *Perisphinctes* (*Lithacoceras*), *P.* (*Pachysphinctes*), *Simoceras*, etc. (Quennell *et al.* 1956).

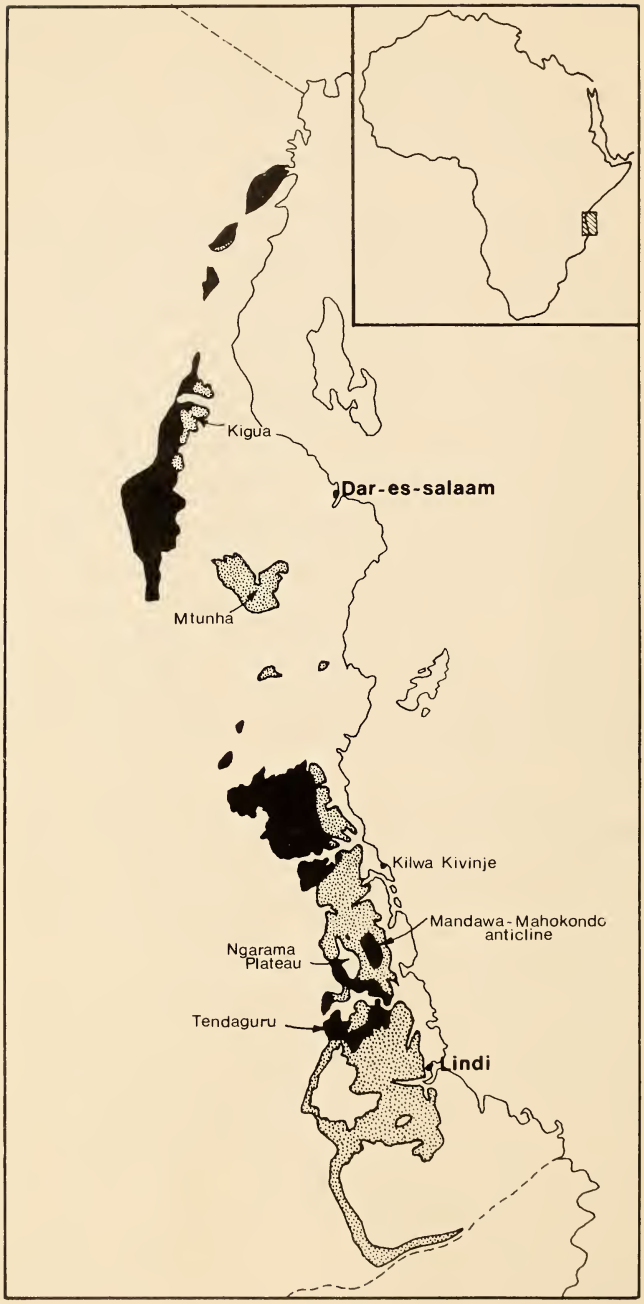

Fig. 8. Distribution of Jurassic (black) and Cretaceous (stippled) strata in Tanzania. After Quennell *et al.* 1956.

From Tendaguru, in the Mbemkuru Valley of southern Tanzania a Lower Tithonian age has been favoured (Quennell *et al.* 1956) for the '*Trigonia smeei* Beds'. The ammonites include *Haploceras*, *Hildoglochiceras*, *Subdichotomoceras*, etc. Above beds with *Trigonia* (*Indotrigonia*) *smeei* (J. Sowerby) occur the non-marine 'Upper Saurian Beds', which are also included in the Jurassic (Quennell *et al.* 1956).

There is an apparent unconformity separating the succeeding '*Trigonia schwarzi* Beds', which have yielded the ammonites *Olcostephanus* (*Olcostephanus*), *O.* (*Jeannoticeras*), *Phylloceras serum* Oppel, *Lytoceras hennigi* Zwierzycki (to which species Zwierzycki (1914) assigned the Moçambique fragments), *Bochianites*, etc. To the north-east of the Mandawa–Mahokondo anticline, Neocomian strata are anticlinally-folded, and unconformably overlain by Aptian strata (Quennell *et al.* 1956). The presence of *Heteroceras*, *Ancyloceras*, *Procheloniceras*, *Cheloniceras* (*Cheloniceras*) *rauffi* (Zwierzycki), and *Diadochoceras nodosocostatum* (d'Orbigny) suggests at least part of the Barremian as well as most of the Aptian to be present, while the occurrence of *Puzosia paronae* Kilian was taken by Zwierzycki (1914) to indicate the Albian. Hennig (1937) recorded *Hysteroceras varicosum* (J. Sowerby), '*Turrilites*' aff. *bergeri* Brongniart, *Phylloceras broilii* Krenkel, *Puzosia kitchini* (Krenkel) (= *Tetragonites kitchini*) and *P. africana* Krenkel *non* Kilian (= *Parasilesites austroafricanus* (Krenkel)) from the Namazatu area, to which he assigned on Albian age. According to Murphy (1967: 36), *Tetragonites kitchini* 'is dated as upper Albian'. Hennig (1937) considered the Cenomanian and Turonian to be absent from Tanzania, although Quennell *et al.* (1956) report Cenomanian strata, presumably based on microfaunal evidence. Furon (1963) considered the Cenomanian to be represented by beds with *Rhynchostreon suborbiculatum* (Lamarck). It seems likely, however, that this species is of an earlier age along the east coast than it is along the west coast. If, as suggested by Reyment & Tait (1972), Africa and Brazil were connected until the early Turonian, then migration of *R. suborbiculatum* during the Cenomanian must have occurred via the eastern shoreline. This species has not yet been recorded from Zululand and does not appear to have migrated this far south by the beginning of the Upper Cenomanian. It is, however, known from the pre-uppermost Cenomanian strata of Catuane (Soares & Da Silva 1970). This suggests that its age in East Africa is either Lower or Middle Cenomanian.

Bate & Bayliss (1973) have recently described the stratigraphy of the Cretaceous succession in the Wami River area, northern Tanzania. The sequence is considered to extend from the Aptian to the Turonian, inclusive. Age determinations are based solely on microfossils, and no macrofossils are reported.

The foraminifers *Rotalipora greenhornensis* (Morrow) and *R. cushmani* (Morrow), together with abundant *Praeglobotruncana delrioensis* (Plummer) were considered diagnostic of the Upper Cenomanian. Middle and Upper Turonian strata are recognized on the basis of the foraminifers *Globotruncana helvetica* Bolli, *G. linneiana* (d'Orbigny), *Hedbergella delrioensis* (Carsey), *Praeglobotruncana stephani* (Gandolfi) and *Clavihedbergella simplex* (Morrow), together with the ostracodes *Cytherelloidea turonica* Bate, *Cytheruna moorei* Bate, *C. lunzangaziensis* Bate, *Curfsina turonica* Bate, *Cythereis luzangaziensis* Bate, *Cytherella afroturonica* Bate, *Akrogmocythere wamiensis* Bate, *Paracypris wamiensis* Bate and *Sphaeroleberis africana* Bate.

It would be most unusual were this succession complete, in view of the fact that breaks in sedimentation are known to exist both to the north and to the south. Consequently, ammonites are needed to corroborate the microfaunal evidence.

The Senonian in Tanzania is known mainly on the basis of microfossils, although Spath (*in* Quennell *et al.* 1956) assigned an ammonite to the genus *Pachydiscus* s.l.

Tavani (1949) considered all horizons from Barremian to Turonian, inclusive, to be present in the Cretaceous deposits of Somalia. No diagnostic Barremian ammonites have yet been recorded, unless *Pseudothurmannia incertus* Tavani is correctly identified, and the presence of this stage is based largely on bivalves and gastropods. Much of the Aptian is present, a rich *Cheloniceras* fauna recording the presence of upper Lower Aptian (*deshayesi–bowerbanki* Zones) strata. The Upper Aptian is represented by beds with *Epicheloniceras subnodosocostatum* (Sinzow), *Parahoplites weissi* Neumayr & Uhlig, *P. rudis* Tavani, *Acanthohoplites* cf. *aschiltaensis* (Anthula), *A. mustahilensis* Tavani, etc. Tavani's (1949) record of *Hypacanthoplites milletianus* (d'Orbigny) suggests the possibility of the presence of uppermost Aptian–lowest Albian (*jacobi–tardefurcata* Zones) strata, beds which appear to be absent from the other stratigraphic sequences of the east coast. This identification should be regarded as tentative, since as pointed out by Casey (1965: 435) 'although it (*Hypacanthoplites milletianus*) is one of the most widely quoted of Albian ammonites, it has been generally wrongly identified'.

Albian strata are known from Bugda Acable where a rich *Douvilleiceras* fauna yielding *D. mammillatum* (Schlotheim), *D. monile* Tavani (*non* J. Sowerby), *D. spinosum* Tavani, *D. benonae* Besairie, *D. variabile* Tavani, and *D. cheloniceratiforme* Tavani indicates the upper Lower Albian (*mammillatum* Zone). Middle Albian strata have yielded *Brancoceras zrissense* Pervinquiére and *B. senequieri* (d'Orbigny), while Owen (1971: 134) considers the occurrence of the endemic lyelliceratid *Somalites vertebralis* Tavani together with *Brancoceras* (although Tavani (1949) records *Somalites* in association with Upper Aptian forms) 'may well indicate the equivalent of the *lyelli* Subzone (Middle Albian)'. The occurrence of a *Hysteroceras* sp. and *Labeceras crassum* Spath provides evidence for the presence of low Upper Albian sediments, although mortoniceratids are still unrecorded.

Tavani (1949: 71) considers the Ferfer Gypseous 'Series' to be of Cenomanian age, as also the base of the Belet Uen 'Series', noting 'qui in Somalia invece il Cenomaniano presenta una estrema scarsità di Ammoniti, rappresentati soltanto da alcuni esemplari appartenenti ai generi *Heterotissotia* and *Placen-*

ticeras'. *Heterotissotia figarii* Greco, known from the Coniacian of Egypt, *H. complanata* Tavani, and *Proplacenticeras tumulicum* (Blandford) are not of Cenomanian age, but are indicative of the Coniacian. Thus, as in Zululand, transgressive Coniacian deposits rest disconformably upon Albian and possibly early Cenomanian strata. According to Furon (1963: 304) the Senonian is known from Somalia by the bivalves *Venericardia beaumonti* (d'Archiac) and '*Exogyra*' *overwegi* von Buch.

THE CRETACEOUS HISTORY OF AFRICA SOUTH OF THE SAHARA

It is now possible to recognize the following Cretaceous history for southern and central Africa. The Africa–South America rift was almost certainly in existence as a rift valley during the late Jurassic–early Cretaceous (Reyment & Tait 1972), with the invading sea reaching Gabon prior to the ?Upper Aptian. Along the east coast rifting began in the north and reached Knysna by at least Upper Jurassic times. With regard to the Jurassic deposits, Klinger *et al.* (1972: 658) noted that 'Occurrences of material comparable to our specimen (*H.* aff. *hildebrandti*) in Kutch and Kenya are thought to be Middle Kimmeridgian (Spath 1927, 1930*a*; Arkell 1956). *Hybonoticeras* also occurs in the Middle Kimmeridgian of Somalia and Ethiopia (Arkell 1956) whilst in Madagascar, where the genus occurs in both Kimmeridgian and Tithonian, the closest comparisons are with forms from Collignon's (1959) Middle Kimmeridgian.' The widespread occurrence of strata of this age along the east coast would seem to date a transgressive episode.

At the end of the Valanginian another marine transgression resulted in the deposits of the Sundays River Formation of the Uitenhage Group (S.E. Cape), the Umgazana and Emboyti Formations of Pondoland, the deposits at Mahibi Hill and Fernão Veloso in Moçambique, and the '*Trigonia schwarzi* Beds' of Tanzania. The Hauterivian appears to have been largely a period of marine regression.

Along the east coast Barremian deposits are known from Somalia and Ethiopia (Furon 1963), Tanzania, Zululand, and also Madagascar. The deposits are generally of limited extent and poorly fossiliferous, although they would seem to date a transgressive episode. Possibly the 'Aptienne inférieure ou ante-aptienne' transgression of Angola (Hoppener 1958) was contemporaneous.

The widespread occurrence of upper Lower Aptian strata in southern Moçambique suggests that this was a period of marine transgression, not Upper Aptian as suggested by Furon (1963: 362), a fact supported by the transgressive Lower Aptian deposits of the Mangoky sector of Madagascar (Haughton 1963: 266). Strata with rich *Cheloniceras* faunas are also known from Somalia and Tanzania, and are undoubtedly related to this transgression. The Upper Aptian was generally regressive, although the sea did not leave the continental margin until the end of the Aptian. In Zululand the Aptian–Albian boundary is a non-sequence (Kennedy & Klinger 1971), as also in Madagascar (Collignon 1963: 2).

By the beginning of the Albian the west coast rift was open at least as far as Nigeria, and the first truly marine transgression, dated at upper Lower Albian (*mammillatum* Zone), affected both east and west coasts, indicating it to have been eustatic in origin. This was followed on both coasts by continuous deposition until the end of the Albian although in Angola, above beds with *Oxytropidoceras*, the Middle Albian is unfossiliferous, suggesting a slight regression. It is thus interesting to note Owen's (1971: 138) remark 'Superficially, it seems that there is in many parts of the Earth a major break in sedimentation, particularly at the top of the Middle Albian. General sedimentation occurred once again in early Upper Albian times.' The *mammillatum* Zone transgression appears locally to have attained its maximum extent only at the beginning of the Middle Albian, e.g. Nigeria, and in the Rodo Valley of Madagascar (Haughton 1963: 264).

At the beginning of the Upper Albian there was a widespread west coast transgression, followed by a slow regression for the remainder of the Albian, with faunal evidence (Reyment & Tait 1972) suggesting West Africa and Brazil to still have been connected during the Middle Albian. Reyment (1969) considers that for a short time during the Upper Albian the South Atlantic appears to have been open along its entire extent. The opening can possibly be related to flooding of the Nigeria–Pernambuco connection by this transgression. The occurrence of Upper Albian strata, apparently overlapping Lower Aptian sediments, near Porto Henrique in Moçambique suggests this transgression was eustatic.

The final break between Africa and South America is believed by Reyment (1969) to have occurred only at the end of the Lower Turonian. With regard to the Cenomanian, Reyment & Tait (1972: 64) wrote 'The role of the Cenomanian in the Atlantic is important. In all cases known to us the deposits of Cenomanian age in the South Atlantic coastal basins accumulated in a regressive sea.'

In Angola, however, Lower Cenomanian strata are known from far inland both at Cabiri and Novo Redondo, while uppermost Albian is not known from these localities. There seems little doubt that in Angola the Lower Cenomanian was a period of transgression. Possibly the somewhat younger beds with *Turrilites costatus* Lamarck along the Mahube River in southern Moçambique are also related to this transgression, resting as they do upon Lower Aptian strata. Following this transgression, there appears to have been a gradual regression until the middle Middle Cenomanian. The highest Cenomanian beds at Novo Redondo in Angola contain *Turrilites acutus*, *Forbesiceras obtectum*, *Euomphaloceras cunningtoni*, etc. A similar regression would appear to have occurred in Nigeria following deposition of beds with *Acanthoceras quadratum* Crick, *Turrilites* sp., *Forbesiceras* sp., etc. In Zululand a rich Middle Cenomanian fauna with *Turrilites acutus*, *Acanthoceras quadratum*, etc., is overlain by poorly fossiliferous sediments of low Upper Cenomanian age, The paucity of fossils in these Upper Cenomanian sediments is possibly related to the slight change in environment caused by this Middle Cenomanian regression. This synchronous

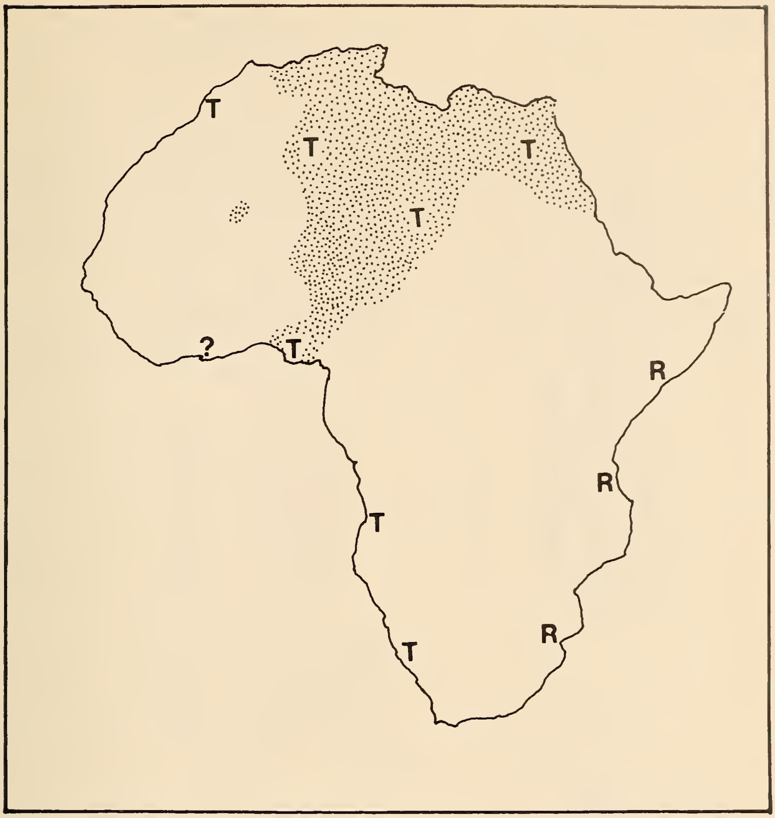

Fig. 9. Africa during uppermost Cenomanian times. T marks the onshore occurrences of uppermost Cenomanian transgressive deposits, with the stippled area indicating the extent of the *Neolobites* transgression in North Africa. R marks Cenomanian localities at which the uppermost Cenomanian is a non-sequence. In part after Reyment 1969.

regression on both sides of the continent suggests the regression was eustatic and not tectonic as suggested by Reyment (1969).

During the uppermost Cenomanian (*Metoicoceras gourdoni* Zone) the sea again transgressed along the west coast, with deposition of the well-known Salinas fauna of Angola, the '*Exogyra* Beds' at Bogenfels in South West Africa, and the beds containing *Metoicoceras* aff. *ornatum* Moreman in Nigeria. This transgression is also indicated by the *Neolobites* faunas of North Africa (Fig. 9). Following this transgression, at San Nicolau in Angola, the sea appears to have remained static, with minimal sediment input (represented by a condensed sequence), until earliest Coniacian times. In Zululand, however, uppermost Cenomanian and Turonian rocks are absent, and low Upper Cenomanian strata are unconformably overlain by Lower Coniacian sediments. The hiatus in Zululand is represented by a hardground, indicating submarine erosion (Rose 1970) and non-deposition. Thus, for almost the exact period represented by the condensed sequence at San Nicolau on the west coast, there was submarine erosion and non-deposition along the east coast. As pointed out by Jenkyns (1971: 330) 'There is an obvious genetic connection between condensed sequences and hardgrounds; condensed sequences are produced by minimal net sedimentation, hardgrounds by nil or negative sedimentation'. Thus, condensation to the west and non-deposition to the east represent slightly differing manifestations of the same regional event.

The absence in Angola of such typical early Turonian forms as *Wrightoceras*, *Bauchioceras*, *Paravascoceras*, *Fagesia*, *Paramammites*, *Nigericeras*, etc., indicates, as suggested by Reyment (1969), that these faunas in West Africa were derived by a transgression from the north, i.e. across the Sahara, the sea only reaching West Africa during the Lower Turonian (Reyment 1971).

At San Nicolau, in Angola, the Turonian–earliest Coniacian condensed sequence is unconformably overlain by alkaline extrusives (Cooper 1972). The absence of pillow-structures together with the unfossiliferous nature of the interbedded sediments suggest subaerial eruption. These volcanics are overlain by a Lower Santonian marine horizon with *Texanites*, *Protexanites*, *Hauericeras*, and *Damesites* (Cooper 1972). Local marginal warping during the Coniacian in Angola can possibly explain the subaerial deposition, the volcanics being related to the tectonic instability of the time. This is supported by the fact that a rich (?)Upper Coniacian fauna with *Peroniceras dravidicum* (Kossmat), *Gauthiericeras margae* (Schlüter), *Barroisiceras haberfellneri* (Hauer), etc., is known from the Ogoové Basin of Gabon (Furon 1963). In South West Africa, Martin (1953) has attributed the reversal of the drainage of the Tsondab Valley, which now flows to the west, as having occurred at some time during the Cretaceous. Possibly it occurred at the beginning of the Santonian.

Along the east coast of South Africa, Kennedy & Klinger (1971: 185) were led to regard the base of the Senonian 'as a diachronous transgressive horizon sedimentation beginning earlier in the north than in the south'. The Mandajene Formation of southern Moçambique can be related to this transgression as can the deposits in Somalia with *Heterotissotia* and *Proplacenticeras*. A similar transgression occurred along the west coast in Gabon, where Coniacian strata rest discordantly upon Turonian rocks (Reyment & Tait 1972), and it would seem to be eustatic in origin.

The Upper Santonian–Lower Campanian appears to have been, in general, a period of regression. Lower Santonian texanitids are common along the west coast, although the only record of Upper Santonian appears to be of a typical *Pseudoschloenbachia* from Cameroun (Reyment *in* Müller 1966: 140). According to Reyment (1966) the Santonian was regressive in the Nigerian basin, while Haughton (1963: 283) noted that the Upper Santonian deposits of the Bas-Zaïre 'are less widespread, a regression having commenced in this substage'. Similarly, Furon (1963: 362) noted that the Santonian was generally

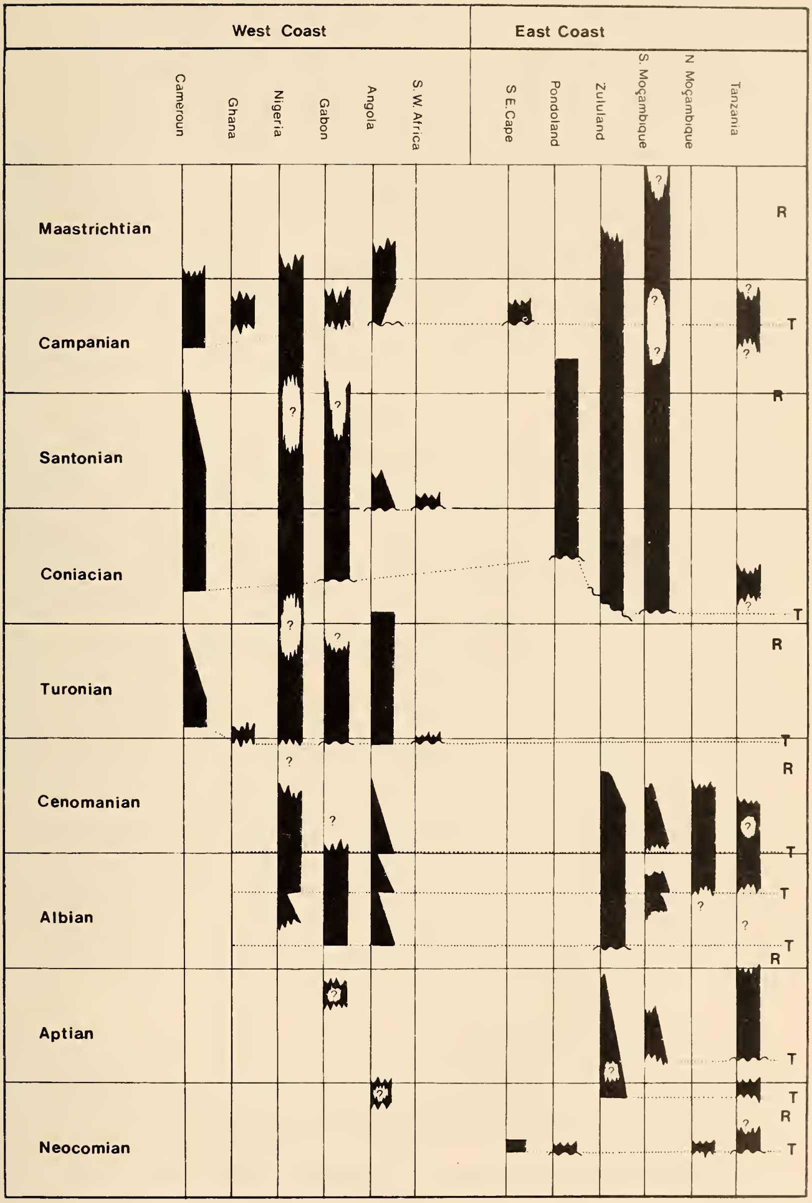

Fig. 10. A comparison of the known Cretaceous stratigraphic sequences along the east and west coasts of south–central Africa. T marks the start of a marine transgression while R marks regressive phases.

regressive in Madagascar. Thus, this regression appears to have been eustatic. The transgressive Lower Santonian of Angola is related to local coastal tilting, and is not thought to be eustatic in origin. The Senonian beds at Bogenfels in South West Africa probably have a similar origin.

A major transgression occurred towards the end of the Campanian, beginning during *Hoplitoplacenticeras vari* Zone times but only reaching its maximum extent somewhat later. The occurrence of similar late Cretaceous outliers at Need's Camp along the east coast, and possibly in the Buzi and Sheringoma regions of southern Moçambique, suggests this transgression was also eustatic. This is supported by the transgressive Upper Campanian deposits of the east coast of Madagascar (Furon 1963).

SUMMARY

A comparison of the Cretaceous sequences along the east and west coasts of southern and central Africa has allowed the recognition of at least nine episodes of marine transgression during the Cretaceous. These are dated at uppermost Valanginian, Barremian, upper Lower Aptian, upper Lower Albian, basal Upper Albian, Lower Cenomanian, uppermost Cenomanian, Lower Coniacian, and Upper Campanian, by the associated ammonite faunas. They appear to best be explained by eustatic changes in sea-level rather than oscillatory tiltings of the African continent.

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